Export of Electronics Equipment Waste

Joseph LaDou, MD

Division of Occupational and Environmental Medicine

University of California School of Medicine

San Francisco, California 94143-0924

(415) 476-4951

FAX: (415) 476-6426

E-mail: joeladou@aol.com

Sandra Lovegrove

E-mail: abelpubserv@aol.com

Abstract

The near absence of effective regulation and enforcement to control the flow of electronics equipment waste ("e-waste"), including computers, computer monitors, television sets, cell phones, and a host other products, is more than an oversight, it is a scandal of epic proportions. To date, industry, government and consumers have taken only cautious and preliminary steps to deal with the e-waste problem. Less than 10% of discarded electronics products are currently recycled. The United States and many other developed countries have exported e-waste primarily to Asia knowing full well that it carried with it a real harm to the poor communities where it would be discarded. In 2006, the European Union put into effect a Directive that bans the use of lead, mercury, cadmium, hexavalent

chromium, and certain brominated flame retardants in most electronics products sold in the European Union. A similar Directive facilitates the development and design of clean electronics products with longer life-spans that are safe and easy to repair, upgrade, and recycle, and will not expose workers and the environment to hazardous chemicals. These are useful approaches to the problem of e-waste, though applying only regionally and covering only a fraction of all the hazardous substances used in electronics manufacture. There is an urgent need for manufacturers of electronics products to take responsibility for their products from production through to the end-of-life, and for much tighter controls both on the transboundary movement of e-waste and on the manner in which it is recycled. Manufacturers must develop and design clean products with longer life-spans that are safe and easy to repair, upgrade, and recycle and will not expose workers and the environment to hazardous chemicals.

Key words: e-waste, electronics equipment waste, printed circuit board, electronics regulations, lead solder, environmental lead, Basel Convention, RoHS, REACH, WEEE, IPP, EuP, RCRA, Take Back, EICC, HARL, LPEUR

Introduction

Electronics manufacture is a major global industry. Its explosive growth has resulted in a world market of more than $1 trillion in electronics products each year, and underlies a large part of the world economy. The demand for electronics products continues to accelerate, while the lifespan of the products

shortens, resulting in an alarming increase in electronics waste equipment ("e-waste"). A billion computers have been manufactured and discarded, and in the next five years, another billion will be repeating the cycle. Many billions of electronics products in addition to computers including television sets, cell phones, air conditioners, appliances, toys, and a host other products have been discarded in every region of the world, a staggering burden on the environment. The rapidly growing e-waste stream presents public health difficulties because a wide range of hazardous metals and chemicals are used in electronics products and in their manufacture.

Less than 10% of discarded electronics products are currently recycled. Many of them are discarded with household trash out of ignorance or disregard of the hazardous materials contained in them. These hazardous materials are serious risks to human health and the environment. The developed countries do not have an exemplary record of attempts to deal with the problem. Instead, they export a great deal of the e-waste to developing countries under the guise of recycling and reuse. As electronics manufacture increasingly moves to Asia, the problem accelerates. China manufactures almost a third of all electronic products used in the world today. China is not taking a lead position among countries to develop a policy to deal with e-waste.

The printed circuit board (PrCB) is a major component of e-waste. The PrCB is the platform upon which electronics components such as semiconductor

chips and capacitors are mounted. Printed circuit boards are found in virtually all electronics products. Asia produces three-fourths of the world's PrCBs, with over 1,000 manufacturers in China alone. Japan produces 29% of the world's PrCBs, followed by China at 17%, then the United States at 15%, Taiwan at 13%, and Europe at 10%. [1]

The PrCB industry requires chemical-intensive manufacturing processes. Toxic chemicals such as glycol ethers have been phased out of some electronics industry manufacture in developed countries, while they are still commonly used in Asia. Large quantities of hazardous chemicals such as formaldehyde, dimethylformamide, and lead are used by the printed circuit board industry. Only recently has there been any serious effort to diminish the quantity of lead distributed worldwide by the printed circuit board industry.

In 1997, the EPA entered into a limited joint effort with the PrCB industry, the Design for the Environment (DfE) project, to identify and assess environmentally safer alternatives to chemical and process technologies that pose potential hazards to workers and communities. [2] Its project with the industry was limited to only one of the many processes necessary to the production of PrCBs. The EPA study resulted in a recommendation that the industry end its widespread reliance on the electroless copper process, and to remove formaldehyde and other carcinogens from the workplace. There is no evidence that this has been done, or even contemplated. The Chinese PrCB industry does

not publish data on chemical usage in its plants. Chinese e-waste disposal practices are state secrets. [3]

Many electronics products also contain brominated, chlorinated, and phosphorus-based flame retardants, phthalate esters, and esters of long-chain organic acids. Following recent EU moves to ban the use of some brominated flame retardants found to be persistent, bioaccumulative, and carcinogenic, a number of U.S. states have enacted legislation that bans their use in consumer goods. Legislation may include tetrabromobisphenol-A (TBBPA), the leading flame retardant used in circuit boards and computer chip casings. Plastic components of electronics products, such as PrCBs, cases, cables, and other structural elements, are likely to be constructed with brominated plastics. There is additional concern over the use of brominated materials due to their potential to generate halogenated dioxins and furans during open burning and improper incineration. [4]

Lead use is ubiquitous in electronics manufacturing. It is present in solder, batteries, paints, finishes, piezoelectric devices, discrete components, sealing glasses, and in heavy concentration in cathode-ray-tube glass used as computer monitors. Lead is also used as a stabilizer for plastics such as polyvinyl chloride, commonly used in cable assemblies. The elimination of lead solder has been a goal of many PrCB manufacturers, due partly to local discharge limitations. Tin-lead solder is easily replaced by tin solder. However, the transition from tin-lead

to tin-only solder has been slow. The early PrCB industry produced electronics products using prodigious quantities of lead and other toxic materials, and systematically shipped them to every corner of the world, where, to this day, they are improperly discarded in landfills, waterways, and incinerators.

Processing E-waste

Discarded computers and other electronics products should be considered as hazardous waste in all countries. About one-half of the heavy metals, including lead, mercury, and cadmium, in landfills come from the e-waste. Discarded computers and other consumer electronics products are the fastest growing portion of the waste stream -- growing almost 3 times faster than the overall municipal waste stream.

In order to recover valuable materials and to minimize the adverse effects of hazardous materials, waste computers are dismantled, then the retrieved materials are sent to specialized facilities for further recycling or treatment. Recycling can recover 95% of the useful materials from the central processing unit (power supply, fan, PrCBs, DVD drive, CD drive, hard disk, soft disk, shell casing, etc.) and 45% of useful materials from the computer monitors (CRTs). [5]

Mechanical processing, such as crushing, screening, as well as magnetic and electrostatic separation separate metal fractions from polymers and ceramics, and are able to obtain more than 50% of the copper, 24% of the tin,

and 8% of the lead. [6] The remaining fraction can be added to cement mortar where no heavy metal ions such as copper, lead, or cadmium are detected in the leachate as a result of the fixation effect of the cement hydrates. [7]

The regulated pollutants most often found in PrCB wastewater are copper, lead, nickel, silver, and total toxic organics. [8] Many other metals associated with the electronics industry are found in wastewater, including barium, beryllium, chromium, cobalt, gold, nickel, silver, and zinc. More than 95% extraction of the gold, silver, copper, iron, zinc, nickel, and aluminum is possible with available technologies. [9]

E-waste contains marketable products including resalable electronics devices and recycled materials such as plastics, metals, and glass. [10] The most costly unit operation is CRT glass recycling. Approximately 50% of the weight of a computer monitor is composed of CRT glass. Thus, the successful recycling of scrap CRT glass can greatly relieve the disposal problem created by scrap monitors. CRT glass may be considered a hazardous waste due to its high lead concentration. [11] Policies restricting or banning some popular disposal options increase disposal costs significantly. [12]

Dopants are chemical materials incorporated into a pure substance to alter its electrical conductivity. Trace elements, such as arsenic, antimony, phosphorous, gallium, and indium, are incorporated into the matrices of silicon-

based chips. These elements are also used in the production of semiconductors, such as gallium arsenide, indium arsenide, or indium phosphide. There has been virtually no discussion of the possible exposures of the general population to "e-waste" resulting from the disposal of outdated semiconductor-containing devices. The potential environmental release of toxic trace elements from semiconductor materials deposited in municipal incinerators or land fills resulting in unanticipated human exposures to these agents in the general population is an important issue. Many of the agents used as dopants are highly toxic and, in several cases, are now identified as known or probable human carcinogens. [13-15] Indium arsenide, indium phosphide, and aluminum gallium arsenide, show clear evidence of carcinogenic potential.

E-waste export

There is an escalating global trade in obsolete, discarded computers and other e-waste collected in North America and Europe and sent to developing countries by waste brokers and so-called recyclers. As much as 80% of the e-waste collected for recycling in the United States is not recycled domestically, but is instead exported to developing countries. [16] The United States and many other developed countries have exported e-waste primarily to Asia knowing full well that it carried with it a real harm to the poor communities where it would be discarded. E-waste is shipped overseas for dismantling under appalling conditions, contaminating the land, air, and water in China, India, and other Asian

nations, Africa, and Latin America. The few informal studies of the public health impact of the recycling efforts around the world give only a glimpse of the true horror this represents to poor countries. [17-21]

In Africa, while there is a legal capacity and ability to repair and refurbish old electronics equipment, as much as 75% of the imports are not economically repairable or marketable. Consequently, the e-waste is inappropriately discarded and routinely burned. Serious adverse impacts on the environment and human health from e-waste recycling continue to occur today due to a lack of regulation and enforcement. China has become the recipient of 70 percent of the world's scrap electronics products, making it the largest electronics garbage dumping ground in the world, according to a recent report by the State Environmental Protection Administration of China. [22]

At workshops in China, India, Bangladesh, and many other countries, lead solder and other metals are dissolved in open acid baths. Some e-wastes are burned on open fires to recover metals from plastics in which they are encased. The open burning, acid baths, and toxic dumping of e-waste introduce unconscionable levels of contaminants into fragile environments, and expose the world's poorest people to a large number of toxic materials. [23, 24] The public health and environmental costs of this recovery process are borne neither by the consumers, nor by the manufacturers of the products. The costs are purposely shifted to the poor people least able to absorb them, and least likely to speak out

against the unfairness of the trade. High levels of toxic lead turning up in cheap jewelry from China have received media attention in the United States. Some of the lead used by these Chinese manufacturers comes from e-waste dumped in China. [25]

Regulation

The current e-waste recycling system is largely doomed to failure before the electronics products ever enter the marketplace. Electronics manufacturers resist or delay efforts to eliminate or substitute hazardous materials, and they are slow to design products for eventual ease of disassembly and recycling. In league with the industry, government fails to hold manufacturers responsible for end-of-life management of their products. Consumers assume an unspecified responsibility for electronics products which they frequently must discard. Left with few choices, consumers readily turn to recycling without realizing that it is an industry with considerable deceit and corruption. [16] The electronics industry has evaded its responsibility for management of products at the end of their useful life, while public policy has failed to promote producer take back, clean design, and safe recycling.

United Nations

United Nations Environment Program (UNEP)

The Basel Convention is a multilateral agreement regulating the international shipment of hazardous wastes. It began in 1987 following many decades of unregulated dumping of hazardous waste in poor countries. The Convention requires that participating nations reduce the transboundary shipment of wastes by minimizing production, and by treating and disposing of wastes as near to the source of production as is possible. Under Organization for Economic Cooperation and Development (OECD) guidelines, non-hazardous wastes exported to recycling facilities do not need to be regulated. The United States and Canada refuse to follow the European nations that define discarded electronics products as hazardous waste. The United States defines computers and other electronics consumer goods as "special wastes," and exempts these wastes from the domestic hazardous waste regulations convention. [26] This creates a loophole for the unregulated exporting of waste electronics products when the exporter claims they are being transferred to an overseas recycling facility. No such loophole exists in the Basel Convention where all discards and residues are considered to be hazardous waste. By signing and ratifying the Basel Convention, EU member states preclude electronics wastes from being shipped to poor countries. Because the United States remains a non-signatory of the Basel Convention, this limitation does not apply to one of the world's largest consumers of electronics products. Although representatives from the U.S. Department of State were actively involved in the Basel negotiations and signed the resulting agreement, the U.S. Senate failed to ratify the treaty. [27]

Europe

Restriction on Hazardous Substances (RoHS)

Environmental management has become increasingly influenced by non-regulatory international standards. The Europeans have taken an important leadership role in facilitating the process. In 2003, the European Union enacted the Restriction on Hazardous Substances (RoHS) Directive that bans the use of lead, mercury, cadmium, hexavalent chromium, and certain brominated flame retardants in most electronics products sold in the European Union beginning July 1, 2006. [28,29] Both business-to-business and consumer products are covered. This Directive, by banning the use of critical materials in electronics products sold in key world markets, may result in a significant change in the way products are designed for global sale. It is anticipated that banning certain core substances from the manufacture of electronics products will drive innovation and substitution. Research and technical assistance on lead-free electronics are developing and are widely acknowledged to be the result of the E.U. Directive.

Unfortunately, the political process has taken its toll, and a gradual weakening of the original intent of RoHS has taken place. There are many exemptions to RoHS, including batteries, and electronics equipment intended to protect national security, or with a military purpose. The U.S. Department of Defense (DOD) was encouraged to stop purchasing lead-containing electronics products, but instead DOD joined the U.S. Department of Homeland Security in lobbying the European Union to exempt the very large defense consumption of electronics products from RoHS restrictions. [30] Moreover, there are specific

applications where higher concentrations of mercury are allowed - including some varieties of fluorescent lamps - and lead has a wide range of exceptions, including higher allowed levels in the glass of cathode ray and fluorescent tubes, in an array of solders, and in electronic ceramic parts. Nonetheless, the ultimate value of the RoHS directive is that many other countries, and over 25 U.S. states, have adopted or are considering similar types of legislation.

Waste Electrical and Electronic Equipment (WEEE)

The electronics industry must take responsibility for its products at the end of their useful life. This responsibility forms the basis for "take-back" legislation which is being implemented in the European Union under the Waste Electrical and Electronic Equipment (WEEE) Directive that took effect in 2005. [31] The WEEE Directive attempts to establish a new management program that could have far-reaching implications for product design and materials management. The Directive encourages the design and production of electronics equipment to take into account and facilitate dismantling and recovery, in particular the reuse and recycling of electronics equipment, components, and materials necessary to protect human health and the environment.

The RoHS and WEEE Directives are intended to address the problem of the increasing waste stream created by electronics equipment. Increased recycling of electronics equipment will limit the total quantity of waste going to final disposal. Producers will be responsible for taking back and recycling

electronics equipment. Consumers will be able to return their equipment free of charge.[32] Extended producer responsibility (EPR) legislation, making producers responsible for financing and organizing take-back and recycling of waste batteries, packaging, end-of-life vehicles (ELVs), and waste electrical and electronic equipment (WEEE), has been or is currently in the process of being implemented in 29 different countries in Europe following introduction of European Union directives. There are presently more than 250 producer responsibility organizations (PROs) established to meet EPR obligations in Europe, which contrasts to the single national recycling schemes founded in the late 1990s.[33]

Regulation, Evaluation, and Authorization of Chemicals (REACH)

The European Parliament and the European Council are advancing legislation entitled Regulation, Evaluation, and Authorization of Chemicals (REACH), that will require industry to prove that chemicals being sold and produced in the European Union are safe to use or handle. REACH policy will require registration of all substances that are produced or imported into the European Union. The amount of information required for registration will be proportional to the chemical's health hazards and production volumes. Companies will also need to seek authorization to sell and produce problematic chemicals, such as carcinogens, mutagens, and teratogens. Toxic chemicals that persist in the environment or that bioaccumulate will also need authorization. REACH is intended to increase the speed and efficiency of the risk assessment process

and to make producers and importers of chemicals responsible for this process. [34]

The REACH proposal gives greater responsibility to industry to manage the risks from chemicals and to provide safety information on the substances. Manufacturers and importers will be required to gather information on the properties of their substances, which will help them manage them safely, and to register the information in a central database. The REACH proposal will have a substantial impact on the global electronics industry. Efforts to restrict the use of carcinogens, mutagens, reproductive toxicants, and persistent and bioaccumulative substances will affect the computer industry and provide a strong incentive to replace these chemicals in products. Opposition in both Europe and America is delaying the progress of the REACH proposal. The electronics industry argued that the proposal is too broad and unworkable, providing a series of recommendations to limit its registration, authorization, and data requirements, and calling for exemptions for polymers and chemical intermediates. Under industry pressure, the U.S. Department of State joined the U.S. Environmental Protection Agency in opposition to the REACH process. [25,35,36] Nonetheless, final adoption of the proposal is expected in 2007. [37]

Integrated Product Policy (IPP)

The European Commission has adopted an Integrated Product Policy (IPP), its strategy for reducing the environmental impact caused by products, and will take a number of actions to stimulate continuous improvement in the environmental

performance of products throughout their life-cycles. [38] The Commission will also initiate the identification of those products with the greatest potential for environmental improvement. After adoption of the Directive, the Commission will be able to enact implementing measures on specific products and environmental aspects such as energy consumption, waste generation, water consumption, and extension of lifetime. Products which have been awarded the Eco-label will be considered as compliant with the requirements of the measure.

Environmentally-Friendly Design of Energy-using Products (EuP)

The Directive Energy-using Products (EuP) provides EU-wide rules for eco-design. [39] The Directive defines conditions and criteria for setting requirements regarding environmentally relevant product characteristics such as energy consumption and allows them to be improved. This proposal will be a model directive under the Integrated Product Policy strategy, and will therefore set for decades to come the standards for better product design. The Directive is an important advance in E.U. product policy and introduces many innovations to existing law. The EuP is expected to increase the effectiveness of other E.U. legislation concerning the environmental aspects of electronics products.

United States

Resource Conservation and Recovery Act (RCRA)

In the United States, environmental regulation is lagging behind the accomplishments found in Europe. The United States has been particularly reluctant to advance legislative solutions to the e-waste problem, and its electronics industry has been unsupportive of efforts by other governments. For a period of decades, the U.S. electronics industry was not regulated for its impact on the environment. The industry has never been required to pay anything close to the actual cost of the environmental damage it has produced. Billions of electronics waste products have been discarded in every region of the world. Not until 1997 did the EPA enter into the Design for the Environment project. By that time, the international pollution of the world with what has come to be known as e-waste was readily apparent.

Since certain components of electronic devices are hazardous due to heavy metal or other constituents, the end-of-life handling of some e-waste is regulated by either U.S. Environmental Protection Agency's Resource Conservation and Recovery Act (RCRA) or State (Health and Safety Code) hazardous waste laws, or both. [40] New regulations regarding the proper management of CRTs found in computer monitors and television sets were recently approved. The United States, with its past reliance on traditional approaches to environmental regulation, only recently began to assume a strong role in international, consensus-based, environmental management standards. Regulatory initiatives are emerging that require the electronics industry to incorporate environmental, health, and safety considerations into design and manufacturing decisions. Moreover, regulations governing the use, storage,

transportation, and disposal of hazardous materials are beginning to influence the manufacturing process.

In 2003, the EPA proposed revisions to the definition of solid waste that would exclude certain hazardous waste from the RCRA if the waste is reused in a "continuous industrial process within the same generating industry." The proposal may eventually exempt all "legitimately" recycled materials from RCRA hazardous-waste regulations. The proposal was intended to exempt recycled electroplating sludge containing a high percentage of recoverable metals from hazardous waste management requirements under the Resource Conservation and Recovery Act, thus reducing the costs of recycling. [41] In 2006, EPA reported that it had withdrawn a draft proposed rule that would have allowed for the recycling of electroplating sludge. According to EPA, it "has decided not to continue with the development of this stand-alone rule addressing recycling." EPA said it may include the proposal in a separate rulemaking that seeks to redefine solid waste. [39]

State Initiatives

Four states have passed e-waste recycling laws, and more than 25 states are at varying stages of adopting RoHS-type legislation. Washington, Maine, California, and Maryland have enacted e-waste legislation. Washington has a free, safe, and simple electronics recycling program without additional taxes or fees for residents. It provides recycling options in every county in the state. Massachusetts, in 2000, was the first state to ban CRTs in its landfills, and in

2006 a new law will require manufacturers to collect their consumer products from the customers after use. California established a funding mechanism for the collection and recycling of computer monitors, laptop computers, and most television sets sold in the state. That law, the Electronic Waste Recycling Act of 2003 also contains a provision that prohibits a covered electronics device from being sold or offered for sale in California if the device is prohibited from being sold in the European Union by the RoHS Directive. [42]

Domestic recycling legislation currently resides at the state level, while international trade operates federally. Because responsible recycling makes products more expensive in a highly competitive market, the electronics industry insists that any e-waste regulation apply nationwide, not state by state, to ensure a level playing field. Industry likes to point out that after the State of California enacted the ban on landfill disposal of e-waste, recycling became the most common end-of-life option in California. As a result of this legislation, the State of California will need more than 60 additional recovery facilities to recycle the number of personal computer systems generated. [43]

Computer Take Back Campaign

The Computer Take Back Campaign is an example of market reform in the place of absent or failed public policy. The Campaign is building substantial momentum for state-level policy reform requiring brand owner financed collection and recycling of hazardous electronics products. Take Back legislation requires electronics manufacturers and brand owners to take responsibility for their

discarded products, both physically and financially. This creates a powerful market incentive to improve product design and reduce the use of toxic materials, which will make recycling cheaper and easier. Model legislation builds off of the EU's Directive requiring brand owners to finance the e-waste collection and recycling system. [44] Shifting the costs for managing discarded computers and other electronics products to brand owners and manufacturers creates a powerful market incentive to improve product design and reduce the use of toxic materials.

Electronics Industry Code of Conduct (EICC)

The Electronics Industry Code of Conduct promotes industry standards for socially responsible business practices across their global supply chains. The code, developed in collaboration with a number of leading electronics manufacturing companies, proposes a standards-based approach for monitoring suppliers' performance across several areas of social responsibility, including labor and employment practices, health and safety, ethics, and protection of the environment. [45] The code reflects the participating companies' commitment to social responsibility and will potentially reduce inefficiency and duplication, and make performance easier to audit and verify.

Fundamental to adopting the code is the understanding that a business, in all of its activities, should operate in full compliance with the laws, rules and regulations of the countries in which it operates. The code encourages participants to go beyond legal compliance, drawing upon internationally recognized standards, in order to advance social and environmental

responsibility. The code may be voluntarily adopted by any business in the electronics sector and subsequently applied by that business to its suppliers. The participating companies invite other companies to review and adopt the code.

Asia

Japan

In 2001, Japan adopted two waste recycling laws that apply to e-waste. The Home Appliance Recycling Law (HARL) covers TVs, washing machines, and air conditioners while the Law for Promotion of Effective Utilization of Resources (LPEUR) is more broadly based and covers eco-design and recycling. Computer manufacturers are required to design products that consider the 3Rs theme. Education of consumers and industry on the 3R themes of reduce, reuse, recycle has been successful. Between them, these account for 18 million appliances per year. The laws require manufacturers to collect and to recycle computers from businesses. The law was expanded in 2003 to include household computers that can be collected and recycled by manufacturers, or collected by the local post office and returned to the manufacturer. The consumer may or may not have paid for the recycling at the time of purchase. [46]

Subsequent to the HARL and LPEUR legislation, the Japanese Ministry of the Environment and the Ministry of Economy, Trade and Industry (METI) suggested a voluntary phase-out of lead, along with increased end-of-life product recycling. Since 2005, the Japanese government has been considering new legislation called the General Law on Constructing Environmentally Sustainable

Society. [47] The Japanese Environment Agency appears to have tried to include extended product responsibility (EPR) clauses in the bill, but industry's firm resistance to any EPR concept made the plan ineffectual. As the plan does not require manufacturers to internalize waste management costs within the price of products and goods, it fails to bring about the intended producers' responsibility. The Environment Agency is unable to advance the EPR concept because Japanese industry as well as the METI express strong disapproval. The result is that Japanese e-waste continues to be shipped to other countries, and the waste producers are free from all legal responsibilities. Japan not only suffers a severe environmental set-back by this policy failure, it establishes a precedent that may influence other Asian countries.

Taiwan

The Taiwanese Environmental Protection Agency declared waste personal computers the producer's recycling responsibility in 1997 legislation. Under this decree, the manufacturers, importers and sellers of personal computers must properly recover and recycle the scrapped computers which they originally sold. In 1998, a producer responsibility recycling program for scrap computers was officially implemented in Taiwan. Currently, only six computer items are mandated to be recycled in this recycling program. They are notebooks, monitors, hard disks, power supplies, printed circuit boards, and main frame shells. [48] Under this program, consumers can bring their unwanted personal computers to the designated collection points and receive payment.

China

In order to ensure that its domestic electronics producers can sell products in the EU market, China has advanced its own RoHS-type law. The Ministry of Information Industry's draft Management Methods for Pollution Prevention and Control in the Production of Electronic Information Products would ban the use of lead, mercury, cadmium, hexavalent chromium, and certain brominated flame retardants in consumer electronics and electrical equipment sold in China. South Korea is also considering the enactment of a RoHS-type law although details are unclear at this time.

Asia has many industrial regulations that are not enforced, and considerable time may elapse before these attempts at regulation are instituted. With more outsourcing and contract manufacturing migrating to south and south-east Asia, there will be increasing requirements for suppliers to the sector to become more aware of environmental issues, especially product-related aspects related to materials reduction, energy efficiency, reduced toxicity and increased recycling. However, outside of subsidiaries of multinationals in south and southeast Asia, small- and medium-sized enterprises have little awareness and understanding of environmental issues and few governments in these countries have initiated programs covering eco-design, hazardous materials substitution and recycling.

Conclusion

The EU Directives on Restrictions on Hazardous Substances (RoHS) and the related Waste Electrical and Electronic Equipment (WEEE) are useful approaches to the problem of e-waste, though applying only regionally and covering only a fraction of all the hazardous substances used in electronics manufacturing. There is an immediate need for much tighter controls both on the transboundary movement of e-waste and on the manner in which it is recycled. There is an urgent need for manufacturers of electronics products to take responsibility for their products from production through to the end-of-life. Manufacturers must develop and design clean products with longer life-spans that are safe and easy to repair, upgrade, and recycle and will not expose workers and the environment to hazardous chemicals.

References

1. LaDou J. Printed Circuit Board Industry. Int J Hygiene & Environ Health. 2006;209:211-219.
2. Environmental Protection Agency, 1997. Design for the Environment. Website: http://www.epa.gov/dfe/
3. Luthje B. Why China matters in global electronics. Int J Occup Environ Health 2003;9:345-346.

4. Morf LS, Tremp J, Gloor R, Huber Y, et al. Brominated flame retardants in waste electrical and electronic equipment: substance flows in a recycling plant. Environ Sci Technol. 2005;15;39:8691-3699.
5. Lee CH, Chang CT, Fan KS, Chang TC. An overview of recycling and treatment of scrap computers. J Hazard Mater. 2004;114:93-100.
6. Veit HM, Diehl TR, Salami AP, Rodrigues JS, et al. Utilization of magnetic and electrostatic separation in the recycling of printed circuit boards scrap. Waste Manag. 2005;25:67-74.
7. Ban, B.C., Song, J.Y., Lim, J.Y., An, K.G., et al. Studies on the reuse of waste printed circuit board as an additive for cement mortar. J Environ Sci. 2005;40:645-656.
8. Chen YH, Chang CY, Chen CC, Chiu CY, et al. Decomposition of 2-mercaptothiazoline in aqueous solution by ozonation. Chemosphere. 2004;56:133-140.
9. Oh CJ, Lee SO, Yang HS, Ha TJ, et al. Selective leaching of valuable metals from waste printed circuit boards. J Air Waste Manag Assoc. 2003;53:897-902.
10. Kang HY, Schoenung JM.a Economic analysis of electronic waste recycling: modeling the cost and revenue of a materials recovery facility in California. Environ Sci Technol. 2006;40:1672-1680.
11. Lee CH, Hsi CS. Recycling of scrap cathode ray tubes. Environ Sci Technol. 2002;36:69-75.

12. Macauley M, Palmer K, Shih JS. Dealing with electronic waste: modeling the costs and environmental benefits of computer monitor disposal. J Environ Manage. 2003;68:13-22.
13. Chen HW. Exposure and health risk of gallium, indium, and arsenic from semiconductor manufacturing industry workers. Bull Environ Contam Toxicol. 2007;78:5-9. 2007;78:123-127.
14. Tanaka A. Toxicity of indium arsenide, gallium arsenide, and aluminium gallium arsenide. Toxicol Appl Pharmacol. 2004;198:405-411. Review.
15. Liao YH, Yu HS, Ho CK, Wu MT, Yang CY, Chen JR, Chang CC. Biological monitoring of exposures to aluminium, gallium, indium, arsenic, and antimony in optoelectronic industry workers. J Occup Environ Med. 2004;46:931-936.
16. Schmidt CW. Unfair trade: e-waste in Africa. Environ Health Perspect. 2006;114:232-235.
17. Basel Action Network. Exporting Harm: The High-Tech Trashing of Asia. Website: http://www.ban.org/#ToOrderExportingHarmTheVideo
18. Greenpeace. Toxic technology contaminates e-waste recycling yards in China and India. Website: http://www.greenpeace.org/international/press/releases/toxic-technology-contaminates
19. Greenpeace. India being treated as a dumping ground. http://www.hindu.com/2005/08/19/stories/2005081904291400.htm

20. China Development Brief. Reporting the latest news on China's social development. Website: http://www.chinadevelopmentbrief.com/node/411
21. Puckett J. High-Tech's Dirty Little Secret. The Economics and Ethics of the Electronic Waste Trade. Chapter 20, in: Ted Smith, David A. Sonnenfeld, David N. Pellow (Eds). Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry, Temple University Press, Philadelphia, PA, 2006.
22. Liu X, Tanaka M, Matsui Y. Electrical and electronic waste management in China: progress and the barriers to overcome. Waste Manag Res. 2006;24:92-101.
23. Wong MH, Wu SC, Deng WJ, Yu XZ, Luo Q, Leung AOW, Wong CSC, Luksemburg WJ, Wong AS. Export of toxic chemicals – A review of the case of uncontrolled electronic-waste recycling. Environ Pollut. 2007; 149(2):131-40.
24. Li H, Yu L, Sheng G, Fu J, Peng P. Severe PCDD/F and PBDD/F pollution in the air around an electronic waste dismantling area in China. ES&T. 2007;41(16):5641-6.
25. Fairclough F. Lead toxins take a global round trip. 'E-Waste' From Computers Discarded in West Turns Up in China's Exported Trinkets. Wall Street Journal. July 12, 2007; Page B1
26. Geiser K, Tickner J. International Environmental Agreements and the Information Technology Industry. Chapter 23, in: Ted Smith, David N. Sonnenfeld, David N. Pellow (Eds). Challenging the Chip: Labor Rights

and Environmental Justice in the Global Electronics Industry, Temple University Press, Philadelphia, PA, 2006.

27. United Nations Environment Program. Basel Convention. Website: http://www.basel.int/

28. European Union, 2003. Directive 2003/ 108/EC of the European Parliament and of the Council of 8 December 2003 amending Directive 2002/96/EC on waste electrical and electronic equipment (WEEE). Website: http://ec.europa.eu/environment/waste/weee_index.htm

29. European Union, 2002. Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS). Website: http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_037/l_03720030213en00190023.pdf

30. National Academy of Sciences. Linkages: Manufacturing Trends in Electronics Interconnection Technology, The National Academies Press, Washington, D.C. 2005. Website: http://books.nap.edu/catalog/11515.html

31. European Union, 2002. Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE). Website: http://ec.europa.eu/environment/waste/weee_index.htm

32. European Union, 2003. Directive 67/548/EEC on the Classification, Packaging and Labelling of Dangerous Substances, Annex 1, as last

amended by Directive 2003/32/EC (28th ATP). Website: http://ec.europa.eu/environment/dansub/home_en.htm

33. Kieren MC. Strategic, financial, and design implications of extended producer responsibility in Europe: A producer case study. J Indust Ecology. 2007;11:113-131.
34. Europa. European Commission. Registration, Evaluation and Authorization of Chemicals (REACH). Website: http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm
35. Thacker PD. U.S. companies get nervous about EU's REACH. Environ Sci Technol. 2005;39:171-172.
36. Petry T, Knowles R, Meads R. An analysis of the proposed REACH regulation. Regul Toxicol Pharmacol. 2006;44:24-32. Review.
37. Lahl U, Hawxwell KA. REACH—the new European chemicals law. Environmental Science & Technology. 2006;40:7115-7121. http://pubs.acs.org/subscribe/journals/esthag/40/i23/html/120106viewpoint_lahl.html
38. European Commission. Integrated Product Policy; Commission outlines its strategy to stimulate greener products. Website: http://europa.eu.int/comm/environment/ipp/
39. European Union. Directive 2005/32/EC on the eco-design of Energy-using Products (EuP). Website: http://ec.europa.eu/enterprise/eco_design/index_en.htm

40. Environmental Protection Agency. Office of Pollution Prevention and Toxics (OPPT). Website: http://www.epa.gov/oppt/index.html
41. Louis GE. A historical context of municipal solid waste management in the United States. Waste Manag Res. 2004;22:306-322.
42. California Department of Toxic Substances Control, 2003. Electronic Waste Recycling Act of 2003. Website: http://www.ciwmb.ca.gov/Electronics/Act2003/
43. Kang HY, Schoenung JM.b Estimation of future outflows and infrastructure needed to recycle personal computer systems in California. J Hazard Mater. 2006;pending.
44. Computer Take Back Campaign. http://www.computertakeback.com/
45. Electronics Industry Code of Conduct (EICC). Global supply chain standards promote socially responsible business practices. Website: http://www.eicc.info/21OCT2004.html
46. Japan: Home Appliance Recycling Law (HARL) . Japan: Law for the Promotion of Effective Utilization of Resources (LPEUR). http://www.moea.state.mn.us/publications/betterbydesign.pdf
47. Inform. Electric Appliance Recycling in Japan. http://www.informinc.org/fact_JapanEPR.pdf
48. Lee CH, Chang CT, Fan KS, Chang TC. An overview of recycling and treatment of scrap computers. J Hazard Mater. 2004;114:93-100.

.